

WADC TECHNICAL NOTE 59-287

SATURATION LIMITS OF WATER IN JET FUEL

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FOREWORD

This report was prepared by the Fluids and Lubricants Branch, Non-Metallic Materials Division. The work was initiated under Project No. 3048, "Aircraft Fuels", Task No. 30178, "Fuel Contamination". It was administered under the direction of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, with Lt. Dale Barsness and A/2C Norman L. Bertram acting as project engineers.

This report covers the period of work from December 1958 to March 1959.

ABSTRACT

A study of the saturation limits of water in current production of jet fuels over a temperature range of 40°F to 90°F was conducted in order to provide data on the effects of water solubility on uninhibited JP-4 jet fuel and JP-4 containing corrosion inhibiting additives. This data is to serve as comparison with data that is received from efficiency tests conducted on various Filter Separator Units.

Within the limits of experimental error, it was observed that the addition of corrosion inhibiting additives to JP-4 jet fuel did not significantly increase the solubility of the water in the fuel.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



BERNARD RUBIN
Chief, Fluids and Lubricants Branch
Non-Metallic Materials Division
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INTRODUCTION

This study was initiated to provide a base line on saturation limits of water in jet fuel for comparison data with efficiency tests conducted on Filter Separator Units, and to provide a comparison of solubility data between uninhibited JP-4 jet fuel and fuels containing anti-corrosion type additives. The fuel samples were tested for total water content using Beckman, KF-3 Aquameter Unit. This is a Karl Fischer Electrometric Titration method.

Uninhibited fuel samples and fuel samples containing Specification MIL-I-25017 additives were saturated statically over an excess of free water throughout the temperature range of 40°F to 90°F.

The three (3) MIL-I-25017 corrosion additives that were studied were:

1. Gulf Agent 178
2. Santolene C
3. Nasul Eds

From this study, results indicate that no change or effects on water solubility is produced by the addition of the corrosion additives to JP-4.

SECTION I. PREPARATION OF SPECIMENS

The test samples were prepared by saturating jet fuel over an excessive amount of water throughout a temperature range of 40°F to 90°F. The fuel was saturated by placing 250cc of fuel over 250cc of water and allowing this mixture to stand unagitated for a minimum of twenty (20) hours at each temperature. The average time these mixtures were allowed to stand was in excess of twenty (20) hours. Control tests were run to determine the efficiency of a twenty (20) hour period for complete saturation. Results of water content (62 ppm) obtained in these tests compared favorably with a 500 hour standing period (58 ppm). From these results, it appears that a twenty (20) hour period should be sufficient for full saturation.

Within the fuel samples, maximum and minimum concentration as well as various combinations of three (3) MIL-I-25017 type additives were added to determine what effect they would have on the saturation limits. The data for these determinations are shown in Table I. These additions were made by weight in (mg/cc).

SECTION II. SELECTION OF MATERIALS

The fuel used in this program was uninhibited JP-4. Uninhibited fuel, as referred to in this report is JP-4 as it is received from the refineries without the addition of Specification MIL-I-25017 anti-corrosion additives. The fuels were layered over distilled water for moisture saturation. The three (3) anti-corrosion additives selected are:

- | | | | |
|-------------------|----------------------------|--------------|------------------------|
| 1. Gulf Agent 178 | (minimum effective amount) | 0.0160 mg/cc | Gulf Oil Corporation |
| | (maximum effective amount) | 0.0580 mg/cc | Petrochemical Dept. |
| | | | P. O. Box 1166 |
| | | | Pittsburgh 30, Pa. |
| 2. Santolene C | (minimum effective amount) | 0.0116 mg/cc | Monsanto Chemical Co. |
| | (maximum effective amount) | 0.0464 mg/cc | Organics Chemical Div. |
| | | | 800 N. Twelfth Blvd. |
| | | | St. Louis 1, Missouri |
| 3. Nasul Eds | (minimum effective amount) | 0.0421 mg/cc | R.T. Vanderbilt Co. |
| | (maximum effective amount) | 0.0580 mg/cc | 230 Park Avenue |
| | | | New York 17, New York |

SECTION III. SELECTION OF APPARATUS

To obtain controlled temperatures on the test samples, a "trop-artic" temperature cabinet was used. Here the test samples were stored at the selected temperature throughout the 40° to 90°F range.

Determinations of the moisture content of the fuel were done by a Karl Fischer Electrometric titration using a Beckman KF-3 Aquameter. The Beckman Aquameter provides a rapid, accurate and convenient means of carrying out the Karl Fischer titration. This fully automatic instrument simplifies moisture determination to such an extent that precise analyses can be made in a few minutes. The Model KF-3 is suitable for materials which are miscible in methanol or from which methanol will extract water as well as for materials not miscible with methanol, such as lubricating oils and jet fuels. A series of controlled tests were run to obtain experimental accuracy of the Beckman Aquameter. From four (4) such controlled tests, a standard deviation of ± 7 ppm or (mg/L) of water was obtained. The confidence limits (95%) for these four (4) tests, gives a ± 11 ppm (mg/L) water experimental accuracy. This compares very favorably with the accepted ± 10 ppm (mg/L) water accuracy of the Karl Fischer Electrometric titration within other laboratories.

SECTION IV. TEST PROCEDURES

The following procedures were used: The Beckman Aquameter was operated in a room with a controlled temperature of 75°F and 50% humidity. The test method for this study is ASTM D1364-55T. The Beckman "Operating and Maintenance Instructions", Manual No. 308-B was followed for use of the KF-3 Aquameter.

The fuel samples were transferred from the storage cabinet with a hypodermic syringe and injected through a rubber diaphragm into the Beckman unit. This method of transfer served to reduce experimental error by reducing contact of the fuel with moisture and other contaminants from the atmosphere.

A minimum of three (3) tests were conducted on each sample and an average of the three (3) results represents the data as reported herein.

SECTION V. TEST RESULTS AND COMPARISON OF DATA WITH OTHER LITERATURE

The data received from this test program are presented in the attached tables and graphs.

Table I gives the water saturation limits obtained from the minimum and maximum concentrations as well as the various combinations of the additives that were added to the fuel. The data obtained with these additives were within the experimental accuracy of the test equipment and therefore, no definite trends could be attributed to the additives. However, it can be noted that the additives produced erratic results as compared to the determinations made with the uninhibited fuel as shown in Figures I and II.

Figure II shows the high and low saturation band for all determinations made between 40°F and 90°F with the various combinations of the three (3) additives. This band appears to be approximately 30 ppm in width of which ± 10 ppm could be attributed to the accuracy of the test instrument and operating conditions. Within this band would also lie the saturation curve, Figure I, of the uninhibited fuel. Thus, within the experimental accuracy, no definite comments can be made as to any change in water concentration due to the addition of the three (3) corrosion inhibitors tested.

From the attached tables of results, comparisons can be made as to the effects on water concentrations due to any one type of the 14 different combinations tested. By a subtraction, as shown in Table II, from the results of the uninhibited JP-4 over water, any one of the additive combinations can be observed as to their effect on an increase or decrease in water solubility under the same conditions and temperature range.

From literature survey, "Effects of Aviation Fuel Components on the Accuracy of the Karl Fischer Electrometric Titration", reprinted from Analytical Chemistry Volume 26, page 1018, June 1954, the data reported on the Karl Fischer titration accuracy was accepted when evaluating the fuels in this study.

Results on water solubility from this study agree closely with the work conducted in December 1956 by the Naval Research Laboratory on "The Solubility of Water in Jet Fuels". The data from the Naval Research study gives water solubility limits an average of 10 ppm larger values than the data obtained from this study. Again, these values agree within the experimental accuracy of the test.

SECTION VI. CONCLUSIONS

The conclusions from this study indicate that the water solubility within jet fuel increases with an increase in temperature. Further study on fuels that were treated with anti-corrosion additives produced results similar to the

water solubility of the uninhibited fuel. Water solubility data on the inhibited fuel was within the experimental accuracy of the test program and therefore, no definite trends could be attributed to the addition of the additives.

TABLE I

Types of Combinations Tested and Water Content

JP-4 over H ₂ O plus Additive				H ₂ O Concentration (PPM or mg/L)					
	Gulf Agent 178	Santolene C	Nasul Eds	40°F	50°F	60°F	70°F	80°F	90°F
JP-4	No additive	No added H ₂ O		20	25	20	10	36	31
JP-4 + H ₂ O	None	None	None	35	40	42	36	65	74
1	Max	----	----	32	39	23	34	62	53
2	----	Max	----	28	47	23	40	63	51
3	----	----	Max	20	47	31	36	65	61
4	Min	----	----	22	45	29	37	65	74
5	----	Min	----	28	44	28	35	65	69
6	----	----	Min	29	38	25	34	66	93
7	Max	Max	Max	21	31	32	38	69	80
8	Min	Min	Min	27	43	37	41	68	78
9	Max	Max	Min	24	41	30	41	71	84
10	Max	Min	Max	25	45	42	50	68	80
11	Min	Max	Max	26	38	35	27	66	70
12	Max	Max	None	24	44	36	39	76	72
13	Max	None	Max	30	46	43	26	63	55
14	None	Max	Max	45	38	28	30	70	62
0.0145 gm 0.0116 gm 0.0145 gm				Max: Additive by wt with 250cc JP-4. 250cc H ₂ O					
0.0040 gm 0.0030 gm 0.0105 gm				Min: Additive by wt with 250cc JP-4. 250cc H ₂ O					

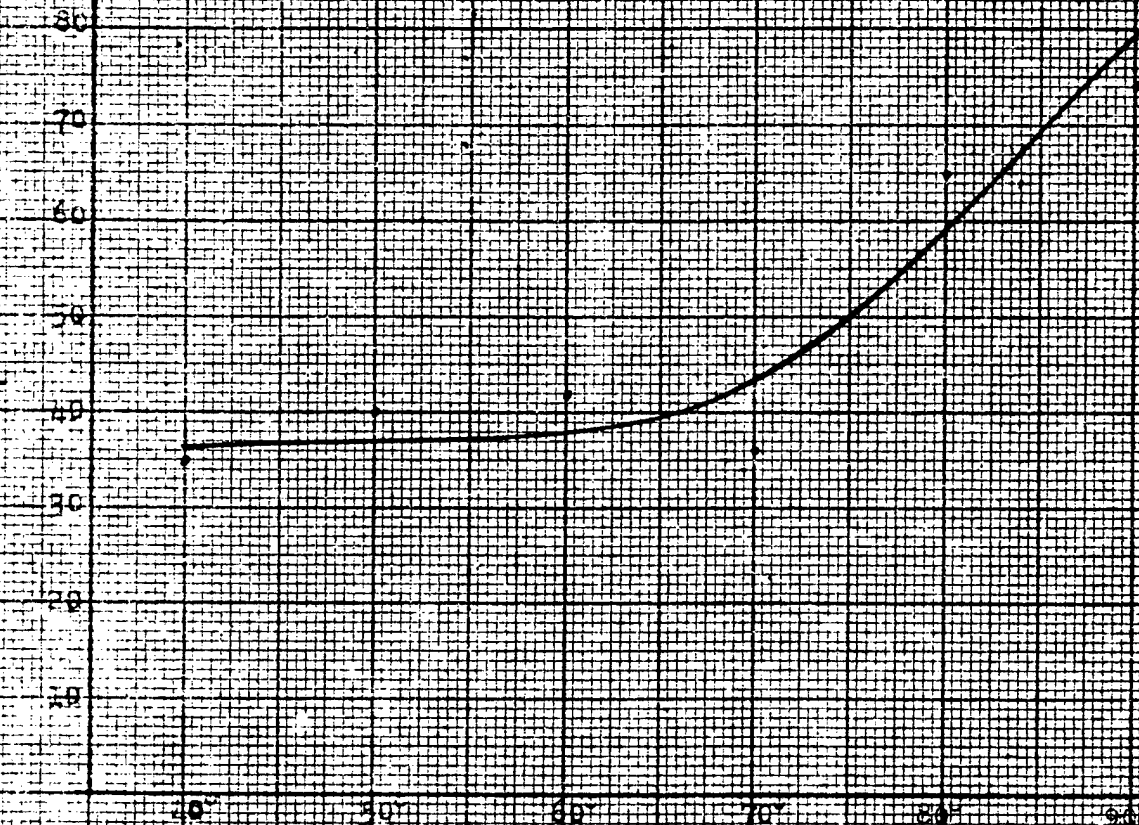
TABLE II

Increase or Decrease in Saturation Level Due to Additives
as Compared with the Uninhibited Fuel

JP-4 over H ₂ O plus Additive				H ₂ O Concentration (PPM or mg/L)					
	Gulf Agent 178	Santolene C	Nasul Eds	40°F	50°F	60°F	70°F	80°F	90°F
JP-4	No additive	No added H ₂ O		20	25	20	10	36	31
JP-4 + H ₂ O	None	None	None	35	40	42	36	65	74
1	Max	----	----	-3	-1	-19	-2	-3	-21
2	----	Max	----	-7	+7	-19	+4	-2	-23
3	----	----	Max	-15	+7	-11	0	0	-13
4	Min	----	----	-13	+5	-13	+1	0	0
5	----	Min	----	-7	+4	-14	-1	0	-5
6	----	----	Min	-6	-2	-17	-2	+1	+19
7	Max	Max	Max	-14	-9	-10	+2	+4	+6
8	Min	Min	Min	-8	+3	-5	+5	+3	+4
9	Max	Max	Min	-11	+1	-12	+5	+6	+10
10	Max	Min	Max	-10	+5	0	+14	+3	+6
11	Min	Max	Max	-9	-2	-7	-9	+1	-4
12	Max	Max	None	-11	+4	-6	+3	+11	-2
13	Max	None	Max	-5	+6	+1	-10	-2	-19
14	None	Max	Max	+10	-2	-14	-6	+5	-12

FE-4 over H₂O NO ADDITIVES

FE-4
or
mg/L



TEMPERATURE °F

FIGURE 1

WHDG TR 57-287

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HIGH AND LOW WATER CONCENTRATIONS OF ALL COMBINATIONS

#1 through #14
See attached Table 1

H₂O
PPM

(mg/L)

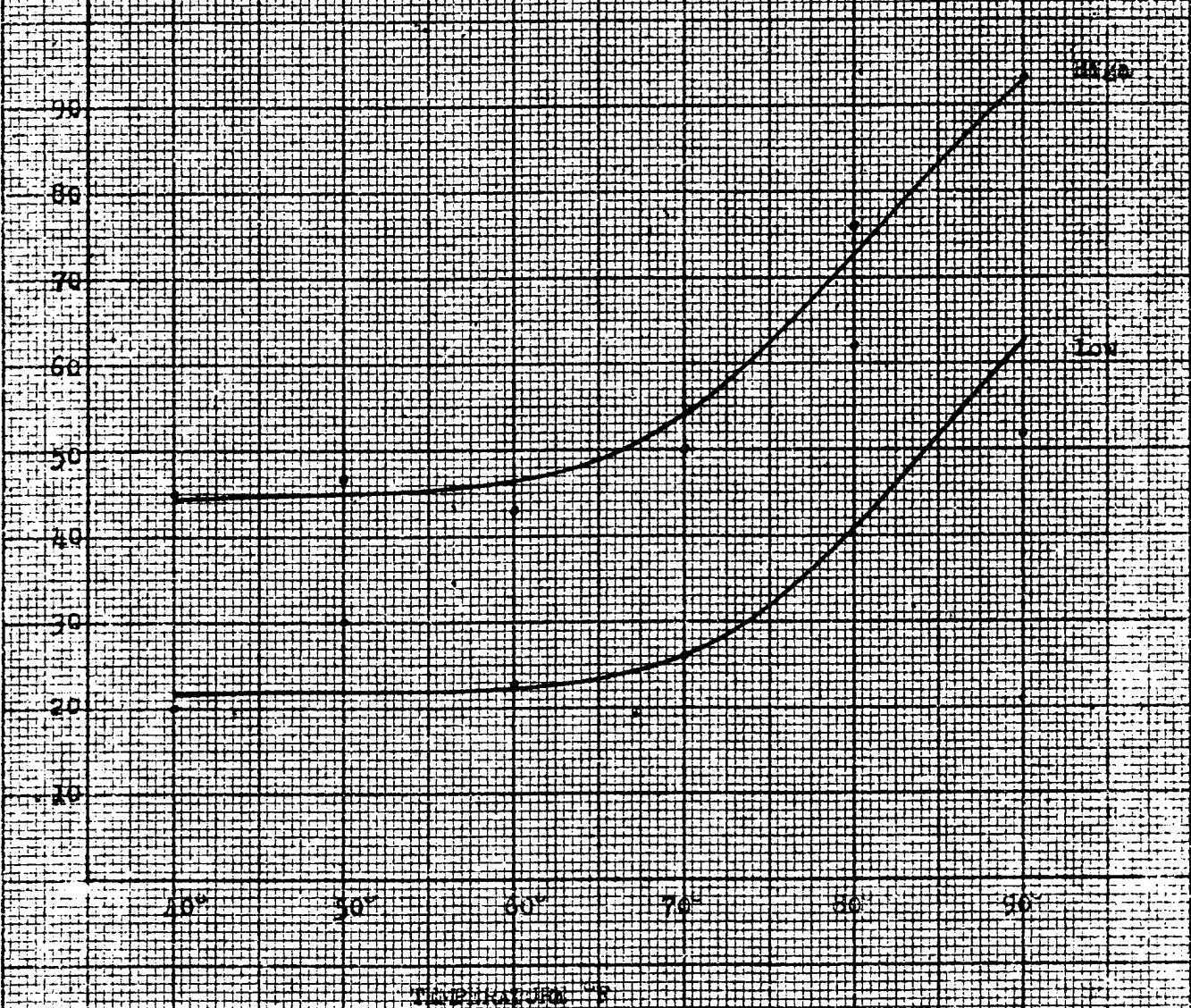


TABLE 2

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BEE 10 X 10 TO 4"

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2. Military Specification MIL-I-25017(ASG), "Inhibitor, Corrosion, for Aircraft Engine Fuels", 20 October 1954, MIL-I-25017(ASG) Amendment I, 15 June 1959
3. Military Specification QPL-25017-4, 27 September 1957
4. "Effect of Aviation Fuel Components on the Accuracy of the Karl Fischer Electrometric Titration". Reprinted from Analytical Chemistry, Vol. 26, Page 1018, June 1954.
5. "Water in Lacquer Solvents and Diluents", (Fischer Reagent Titration Method) ASTM D1364-55T.

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